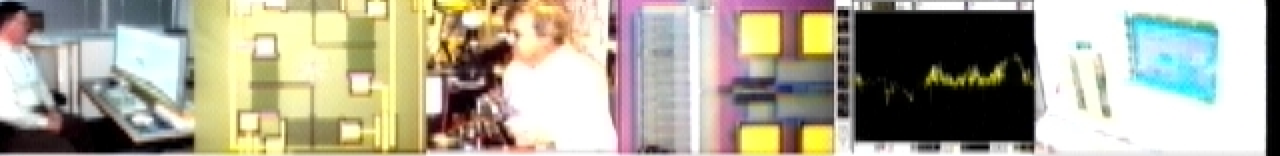


Hardware Devices Group

Group Overview

Barry Brumitt
Gary Starkweather
Mike Sinclair
Turner Whitted

H/W Devices Research

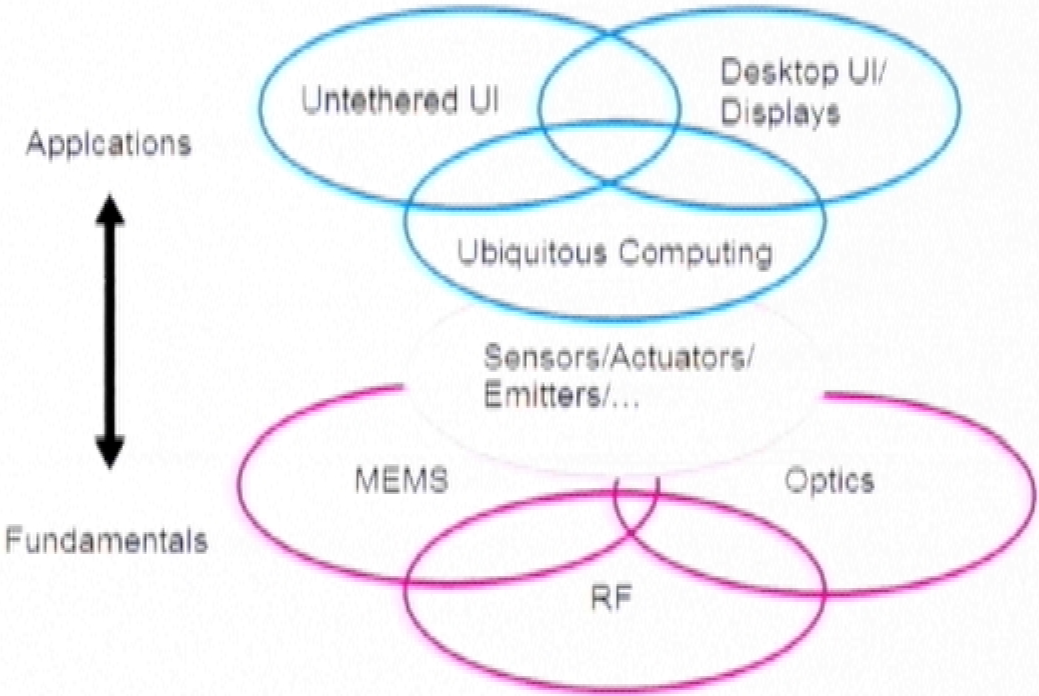
- Mike Sinclair, Senior Researcher
  - MEMS, Sensors, Multimedia, UI
- Gary Starkweather, Architect
  - Novel displays, Display UI
- Barry Brumitt, Researcher
  - Ubiquitous/invisible/location based computing
- Turner Whitted, Senior Researcher
  - Graphics processors, PANs

Why is a software company researching devices?

Why Hardware?

- When was the last time you wrote software for non-existent hardware?
  - Hardware always leads software
- Hardware with greatest impact on MS software products
  - Displays (large, larger, very large, …)
  - Memory (NVRAM, fast DRAM)
  - Interconnect (WAN, LAN, PAN, chip-to-chip)
  - Sensors (user state, machine state)
- Never bet against the hardware!

Technology spectrum



Projects

- Displays
  - Use (measurement, processing, ClearType)
  - Technology (IMODS)
- MEMS
  - Novel actuator projects
- UI
  - Sensor-based experiments
- Invisible/Ubiquitous Computing
  - More sensor-based experiments

technology

High Aspect Prototype (2001)

- ***Twin projector display***

- **A version of this display was shown at the MSR TechFest in 2001.**

Large Displays

- ***Why Large Displays?***
  - **Some logical reasons**
    - Would you like your office desk to be the same size as your display? Or vice versa?
    - Today's "large" displays such as a 21" CRT comprise only a few percent of the physical work area in an office.
    - Many UI issues and constraints revolve around not having enough display area to use.

Experimental Hardware

- *What about user performance?*
  - Early large display prototypes
    - In 1999 and 2000, the HDG built some dual display systems using projectors.
    - These systems used two XGA projectors to make a 2048 x 768 pixel display that was about 12 x 34 inches in size. (2.66 to 1 aspect ratio)
    - MSR UI researchers (G. Robertson, M. Czerwinski and D. Tan) found out that significant performance improvements were realized over smaller displays.*

    - *Tan, D.S., Robertson, G.G. & Czerwinski, M. (2001). Exploring 3D Navigation: Combining Speed-Coupled Flying with Orbiting. Proceedings of CHI 2001. ACM Press.

DSHARP - The triple display (2002)

- DSHARP stands for Display System using High Aspect Ratio with Projection.
- The prototypes use a Matrox G-200 Quad display card although newer video cards are being evaluated.
- Screen pixel density is about 70 dpi.
- Screen luminance is about 900+ cd/sq. meter or about 6 times brighter than your ordinary desktop display.
- The high luminance reduces eye fatigue and significantly improves color saturation.
- The Hardware products group is providing the capability for additional units if desired – Mike Holm.

DSHARP

- *Triple display – 4 to 1 aspect ratio*

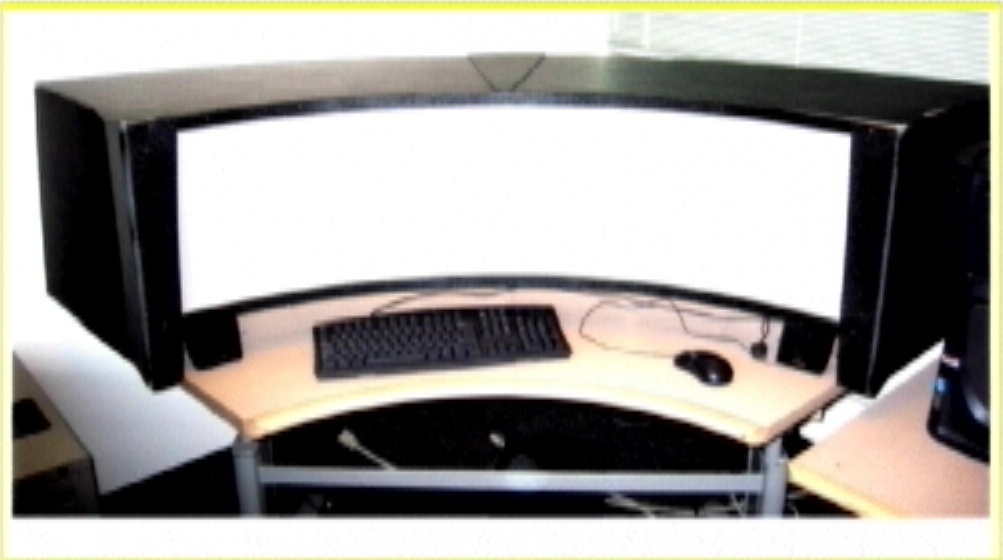
High Aspect Prototype (2001)

- ***Twin projector display***

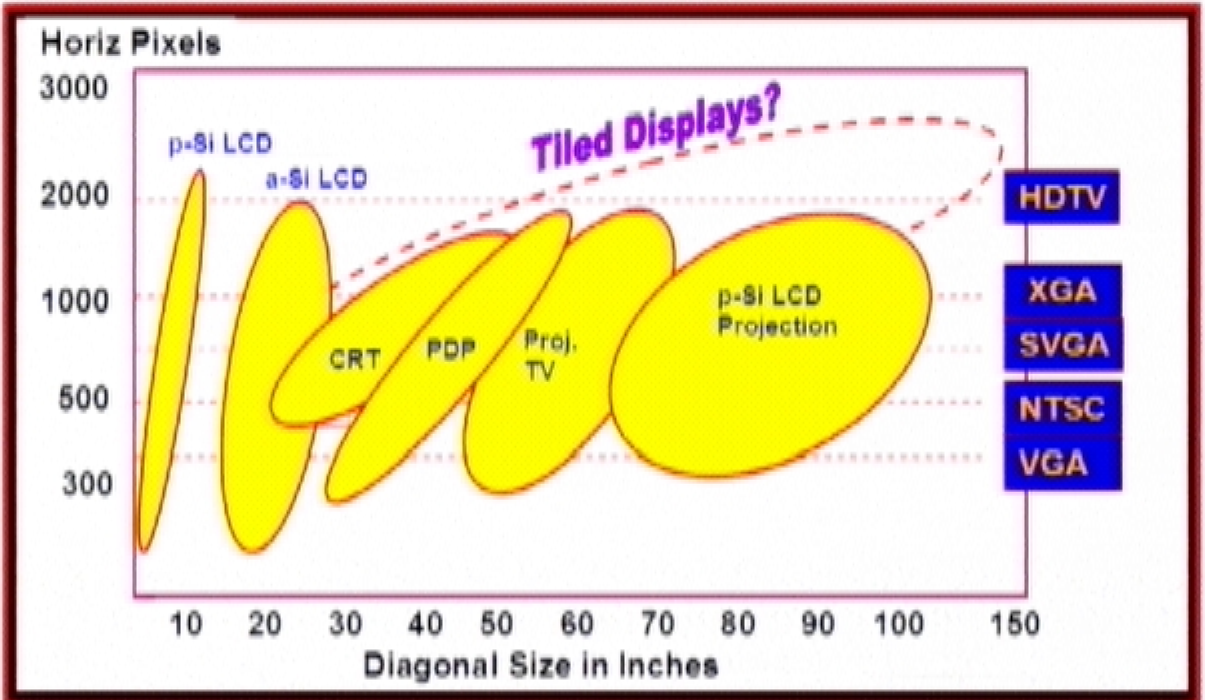
- A version of this display was shown at the MSR TechFest in 2001.

DSHARP

- *Triple display – 4 to 1 aspect ratio*



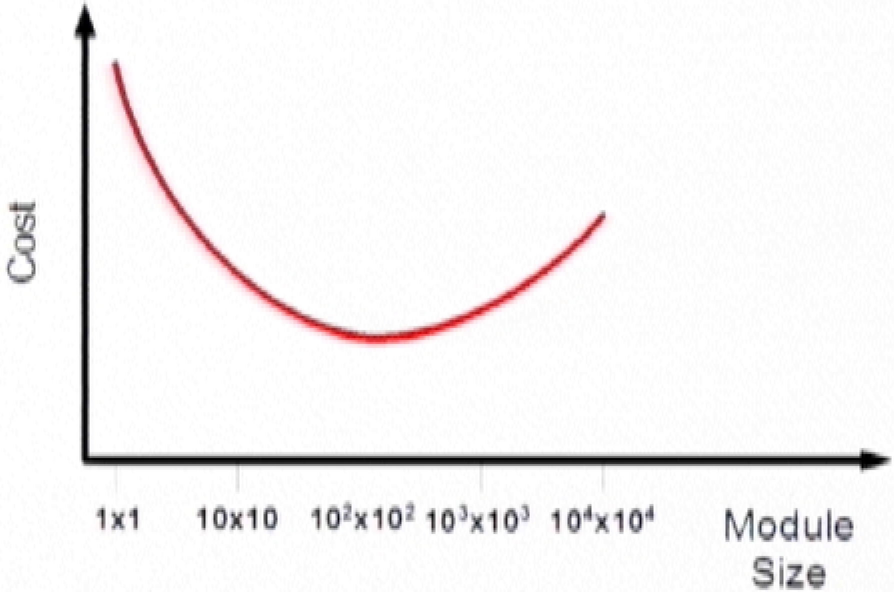
Technology Choice?



What about lower cost and new technology?

- *Practical high volume large display products similar to DSHARP could result from:*
- *(1) Lower cost projection – rather than DLP one might use LCoS (Liquid Crystal on Silicon).*
- *(2) OLED (organic LED) displays made into sheets.*
- *(3) Arrays of mini or micro projectors to provide a "quantized" spatial display element.*
- *(4) Hybrid systems using optics and MEMS.*

IMODS – Integrated MEMS Optical Display



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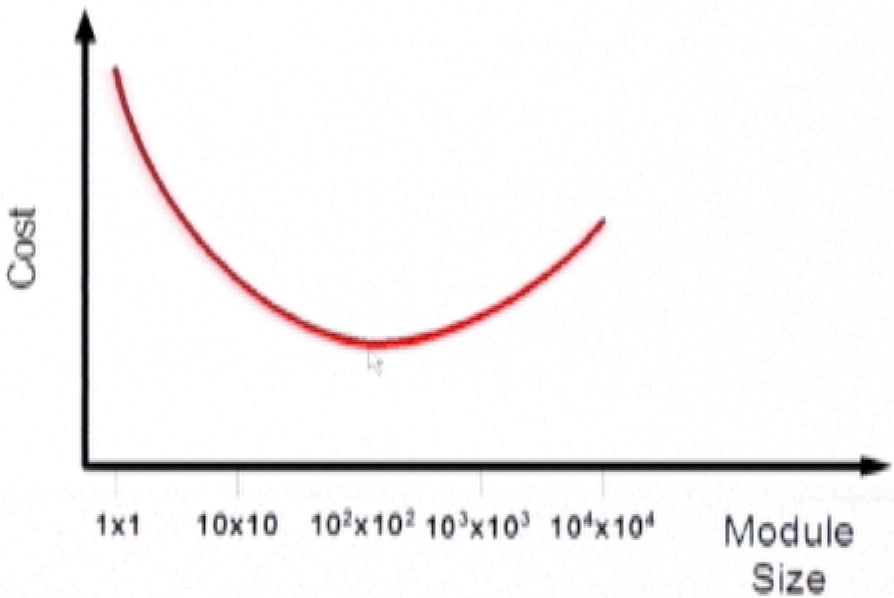
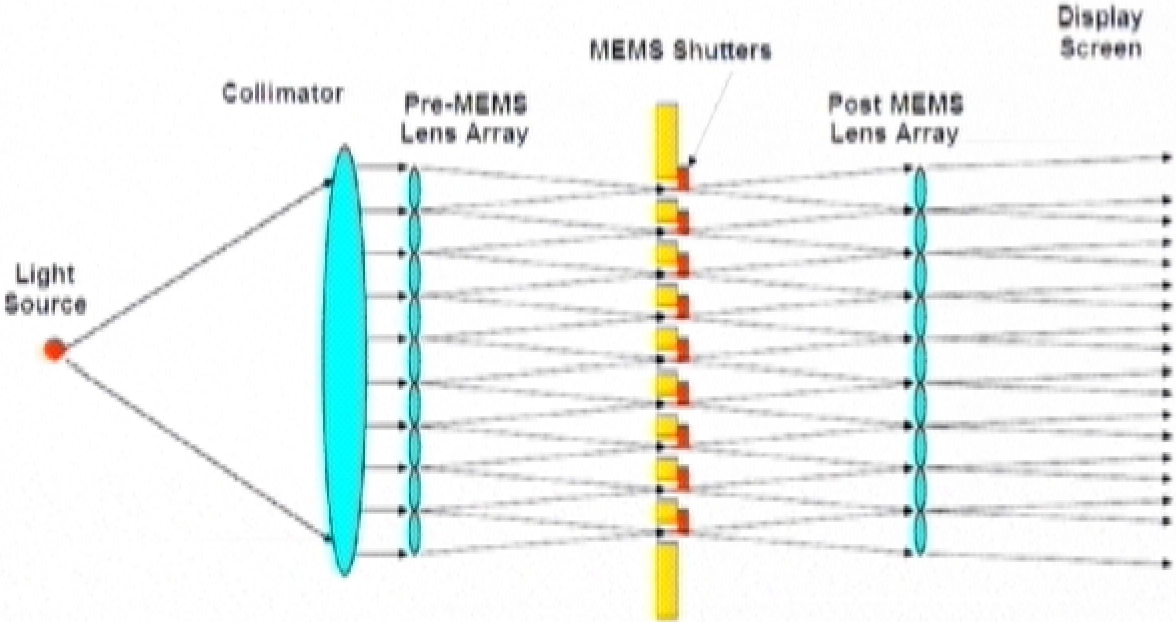


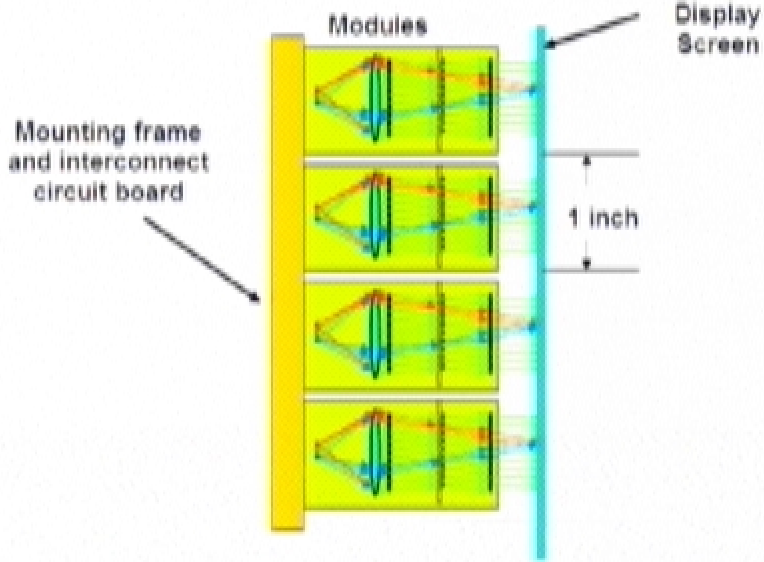
What is the best way to achieve a product?

- *Our concept has been arrays of tiny projectors.*
- *If we want a 5 megapixel display, then 1K $4 projectors with 5 kilopixel resolution would suffice.*
- *How might we make a $4 to $5 projector?*
- *Using 5 ,000 pixel modules could be an important and key solution.* ****
- *If each module covers a square inch then displays would be aspect ratio and shape variant.*
- *The economies of scale apply to the module, not the finished display. This is not unlike ICs.*

IMODS – Integrated MEMS Optical Display



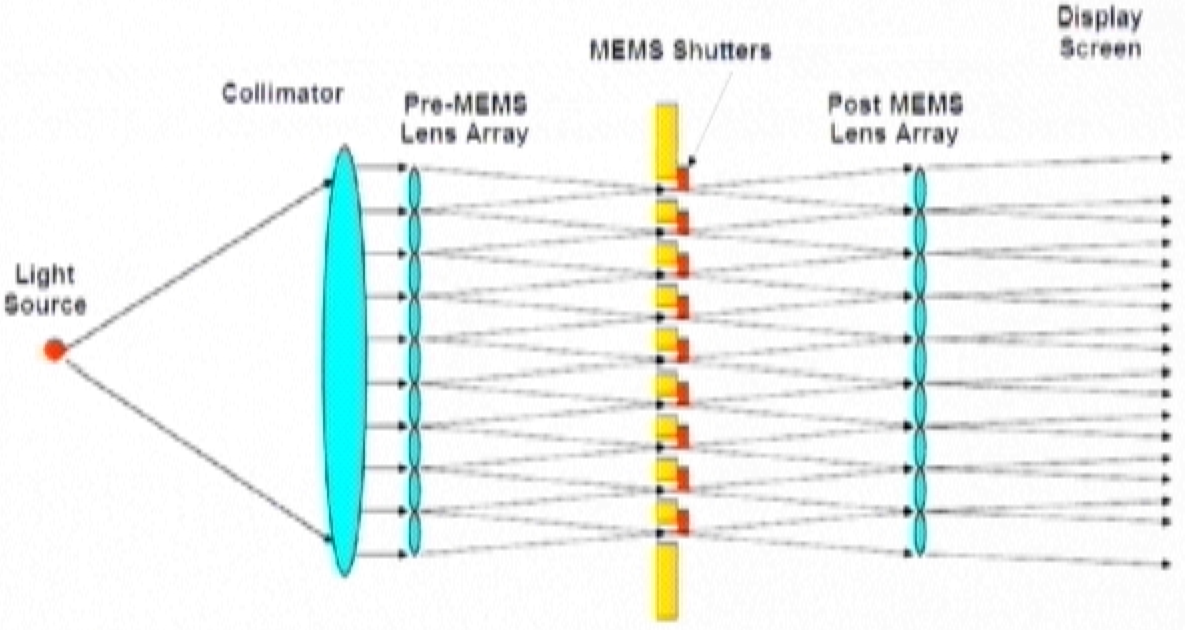
IMODS – Integrated MEMS Optical Display



IMODS – Integrated MEMS Optical Display

- Make a functioning IMODS module that at least turns a few pixels on and off and evaluate whether a transmissive mode (IMODS) or reflective mode (RIMODS) is the best option.
- Work with product groups like the hardware products group (Mike Holm and Dawson Yee) to begin technology development/transfer.
- Continue to evaluate alternatives with a large display capability being affordable by most users.
- The goal is to make DSHARP like displays "thin" and very affordable.

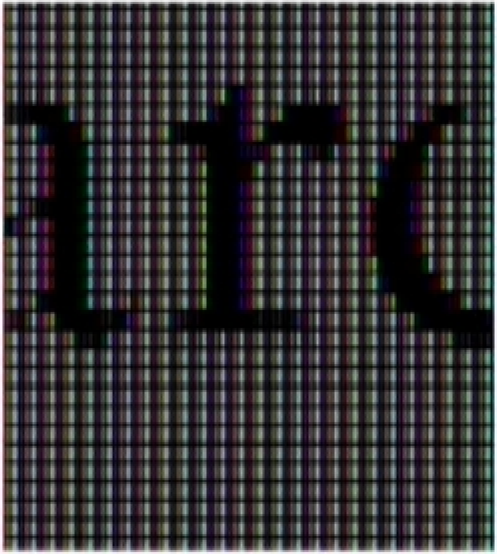
IMODS – Integrated MEMS Optical Display



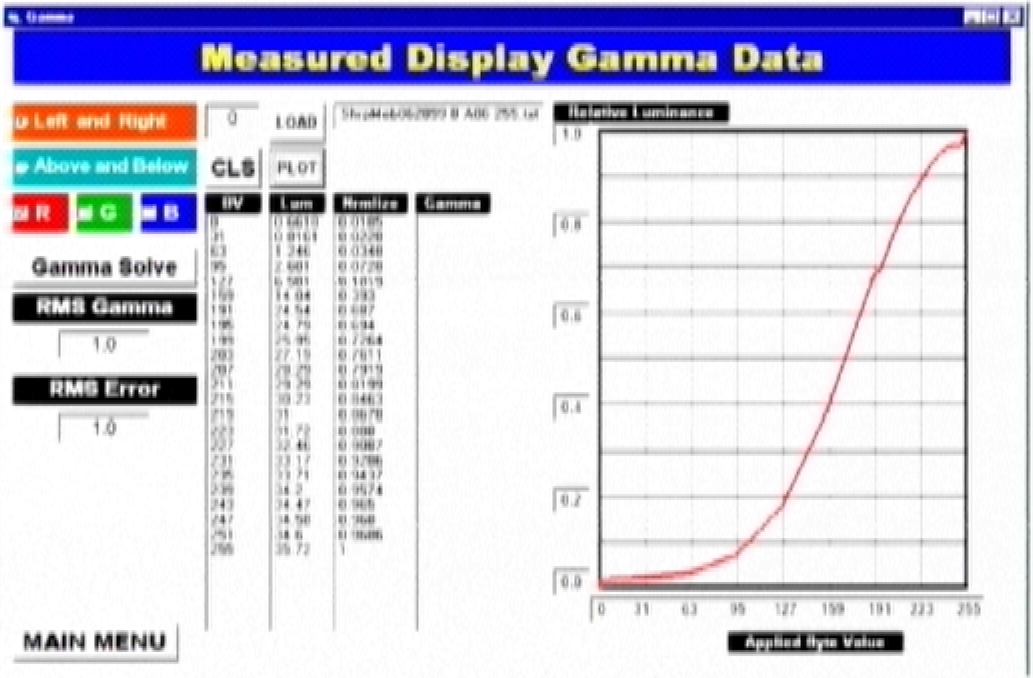
Display characterization

ClearType™

- Resolution enhancement for LCDs
- Optimization according to device characteristics



Measured response



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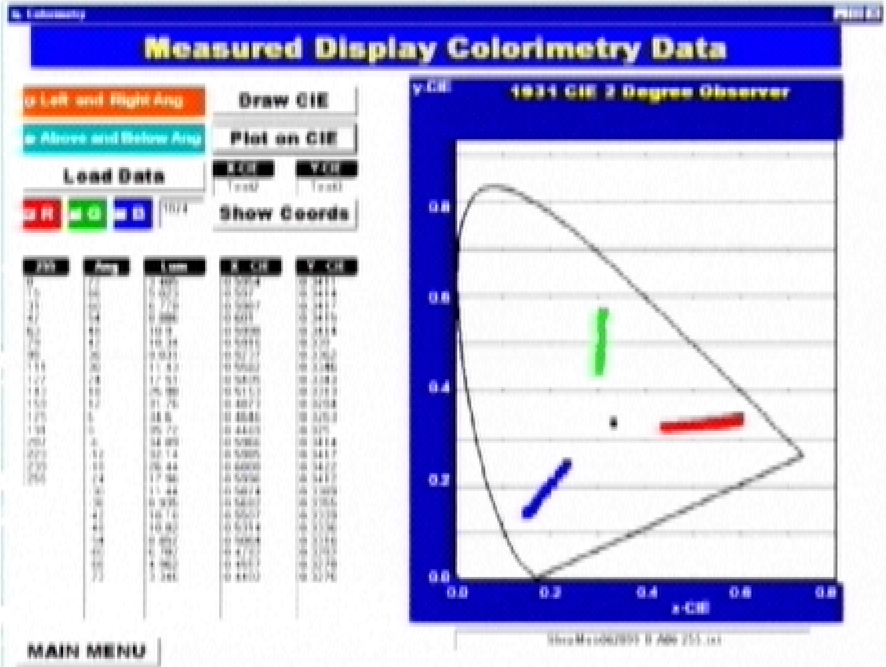
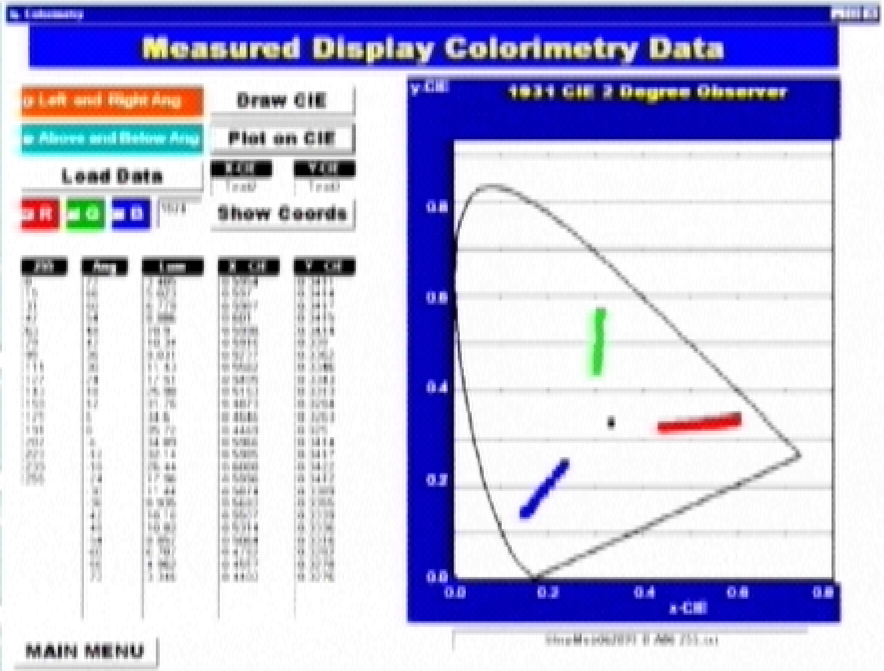
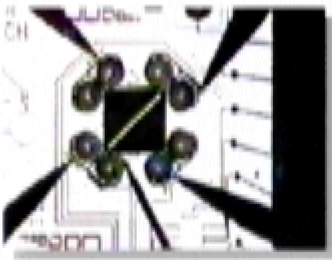


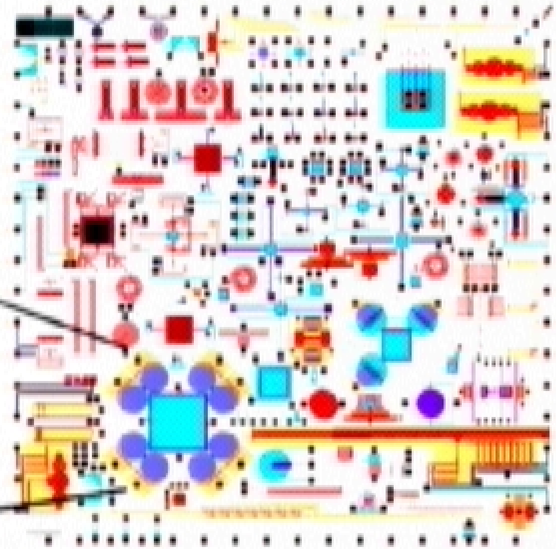
Measured response



Basic technology: MEMS

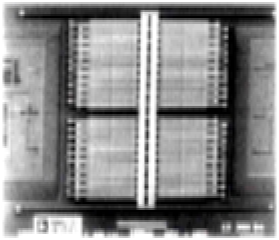
- Sensors integrated into circuits
- Low-power actuators



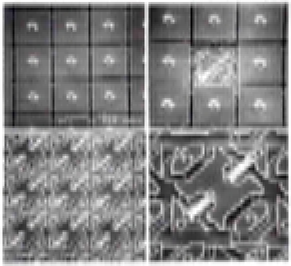


Mike Sinclair, MSR

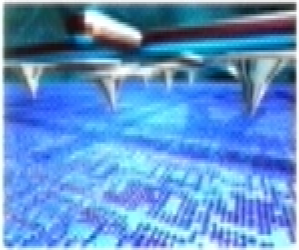
MEMS Applications



- Accelerometer (1, 2 and 3 axes)
  - Air bag deployment
  - Tilt sensor
- Pressure sensing
  - Automotive environment sensing



- Display
  - TI's micro-mirrors - ~1 million tiny mirrors each toggling at 100 KHz
- Mass storage (future)
  - *Many* read heads
  - ~10GB/cm^2
  - Small & cheap



MEMS Fabrication

- Bulk micromachining (etching)

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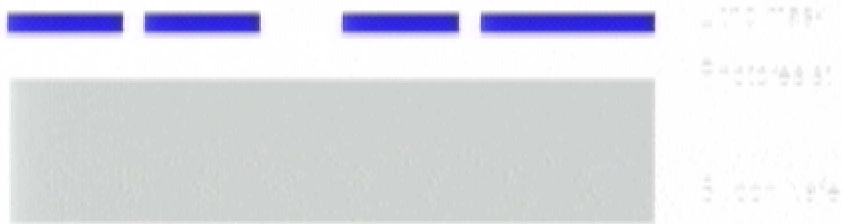

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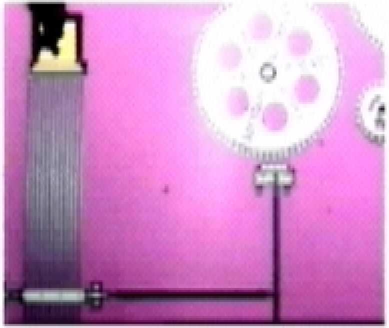
MEMS Fabrication

- Surface micromachining (deposition + etching)



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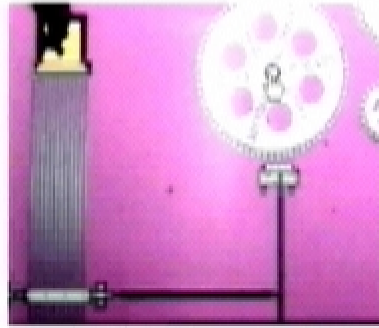

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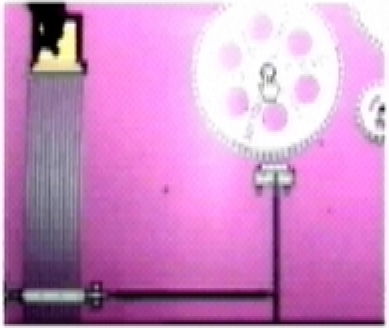

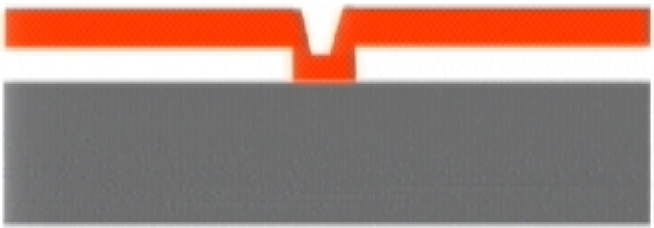

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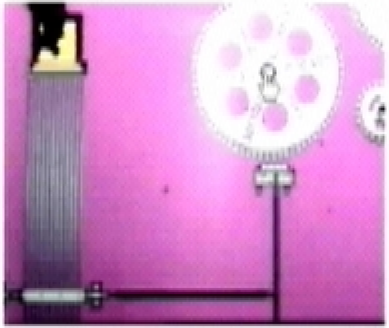

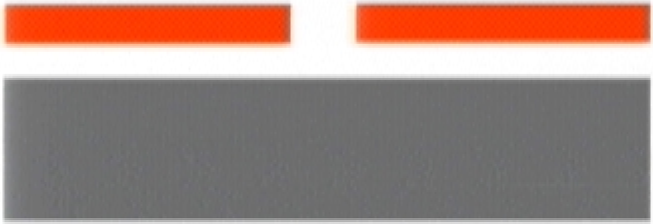

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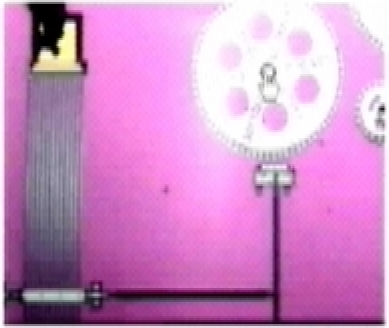
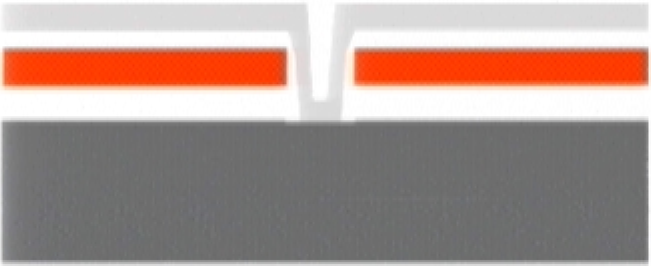
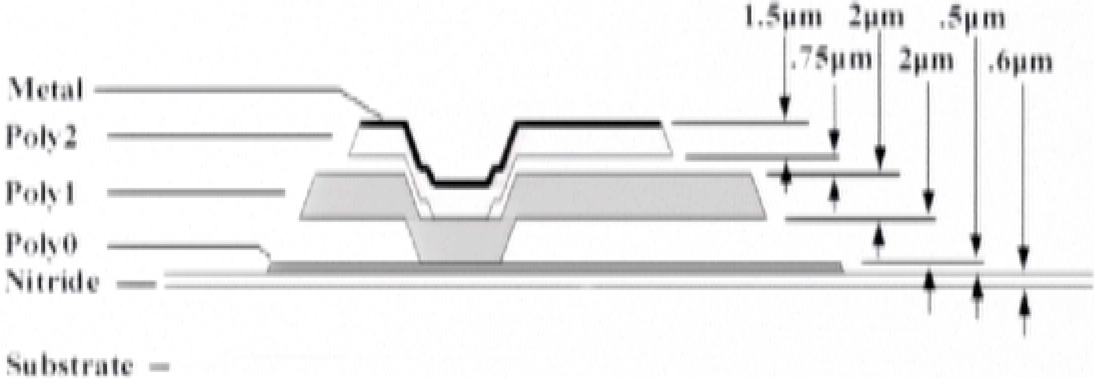




MUMPs (Multi-User MEMS Processes)

Cronos – www.memsrus.com

3 polysilicon structural layers – 2 released + gold layer



Early Work – Thermal Chevron Actuator (in-plane movement)

- Ohmic heating causes beams to expand
- 5v @ 120ma excitation
- 2 KHz frequency response (half amplitude)
- >20 µm no-load deflection
- 180x force/area over common electrostatic drive
- Device genesis – 2D mirror scanner…………

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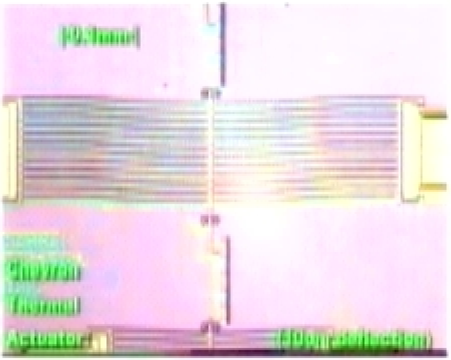

Buckle-Beam Actuator – out-of-plane torque from electrothermal expansion

- Doubly-clamped cantilever

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- Doubly-clamped cantilever
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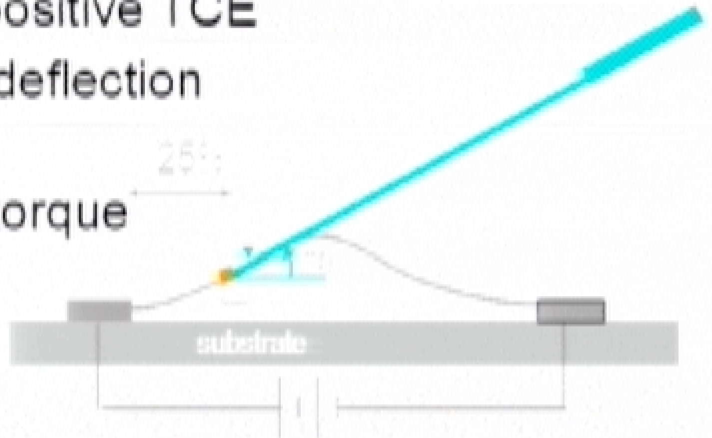
- Exploit maximum deflection derivative
- Add a transverse torque beam, lifting arm and a mirror



Buckle-Beam Operation

- Doubly-clamped cantilever
- Joule heating + positive TCE
- Exploit maximum deflection derivative
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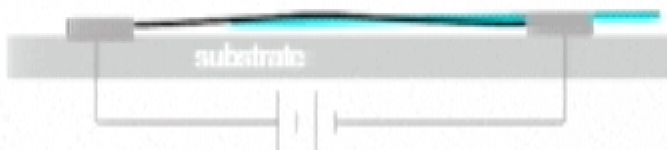
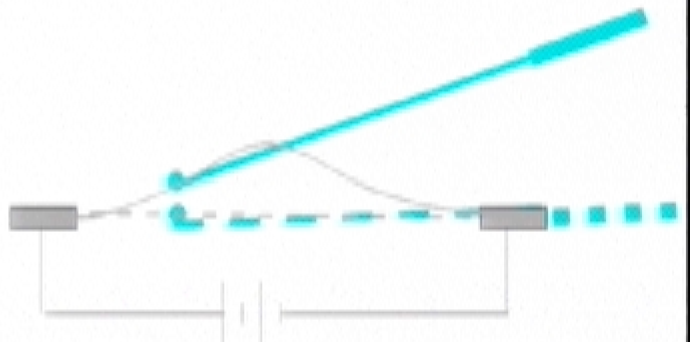
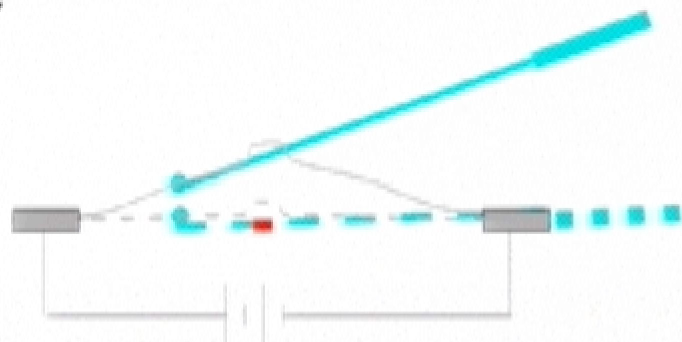


Buckle-Beam Enhancements



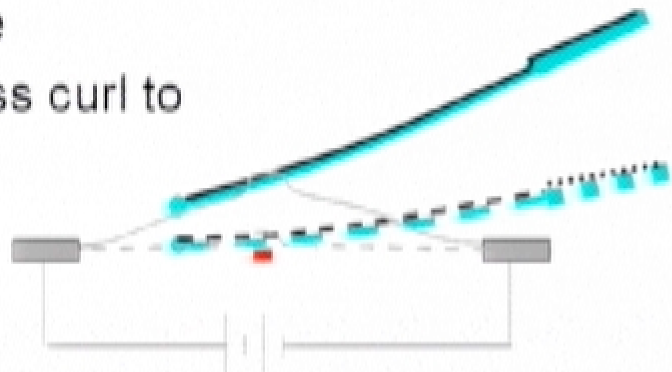
Buckle-Beam Enhancements

- Add spacer beneath beam - provides a conformal bump for vertical asymmetry ⇨ out-of-plane buckle preference



Buckle-Beam Enhancements

- Add spacer beneath beam - provides a conformal bump for vertical asymmetry ⇨ out-of-plane buckle preference
- Use residual stress curl to elevate mirror off substrate



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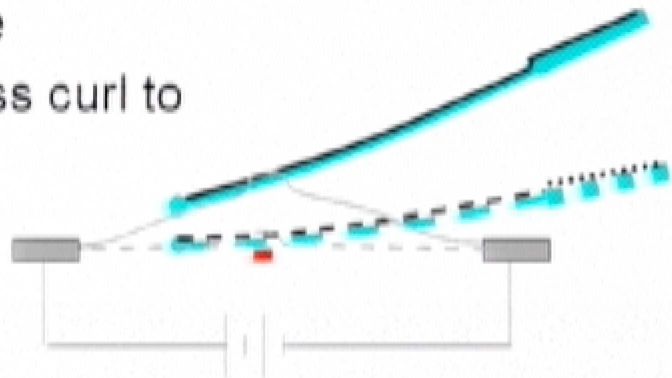

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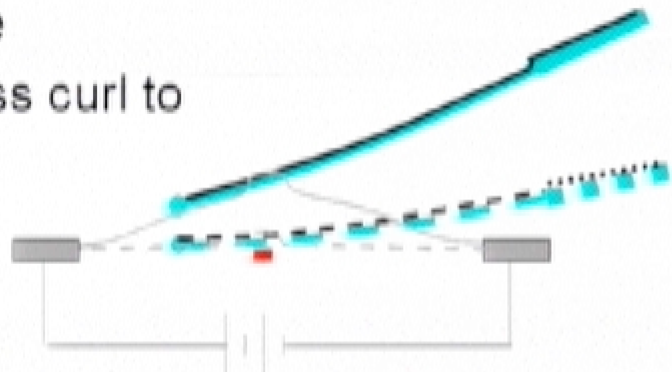

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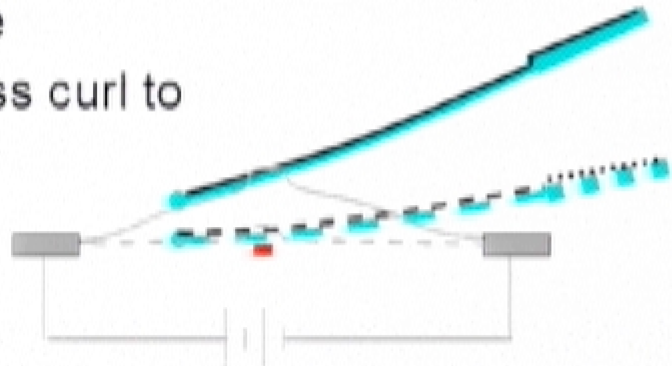
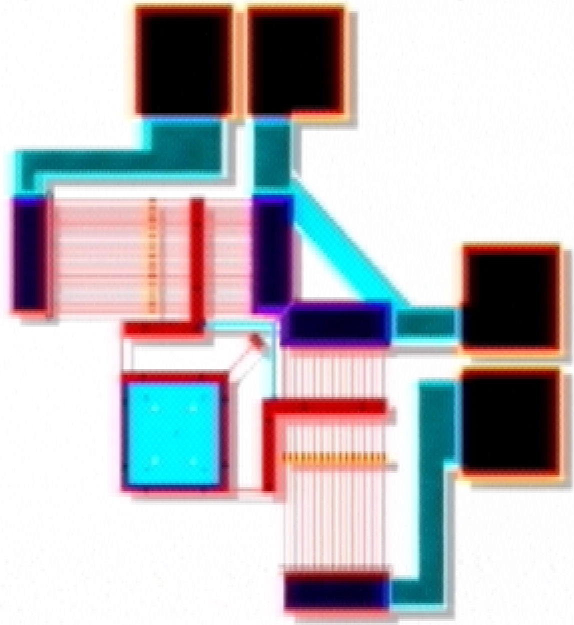


2D Electrothermal Mirror – Vector Display (non-resonant)



2D Vector/Raster Display

- 2D mirror scanner
  - 80 µm² mirror
  - orthogonal actuation
  - 8 deg deflection (optical)
  - 3 KHz frequency response (half-amplitude)

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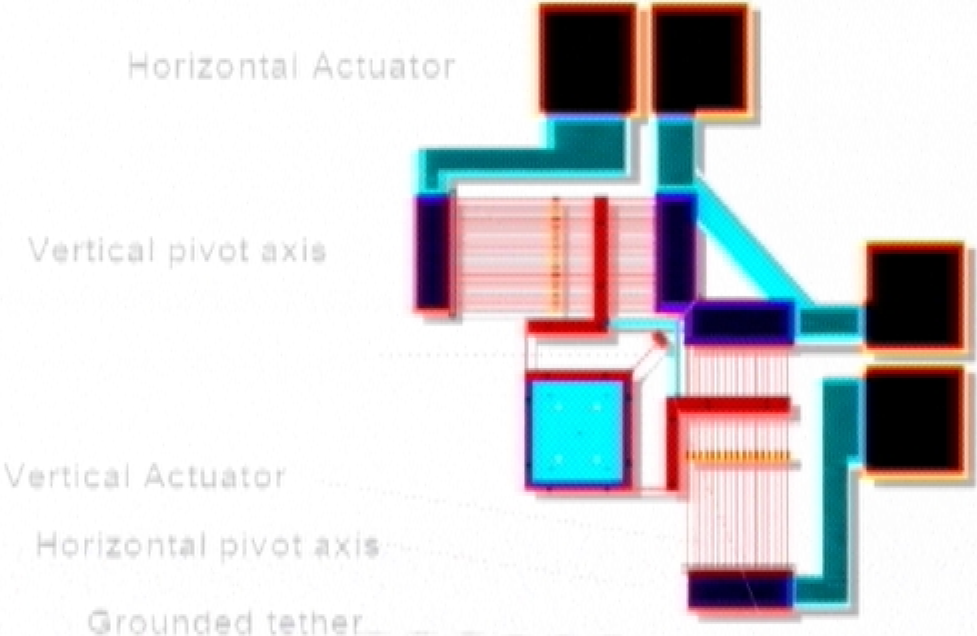

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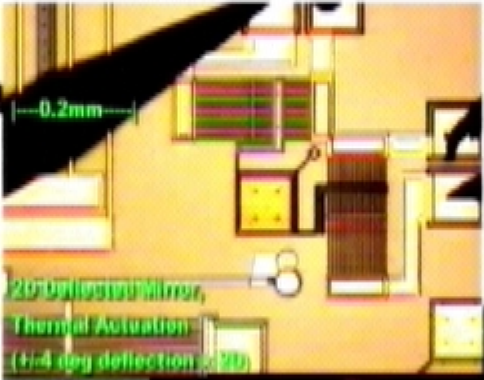
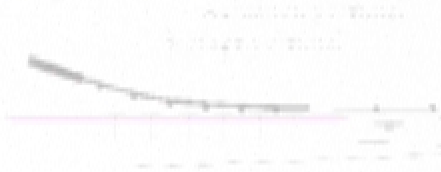
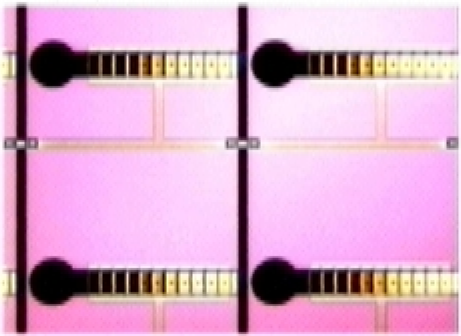


MEMS-based IMODS Displays

small cheap modules for tile-able displays

MEMS Mirror Array (binary)
(6x6 array for prototype)





MEMS-based iMODS Displays

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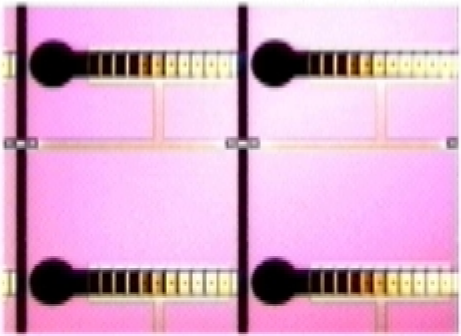


MEMS-based iMODS Displays

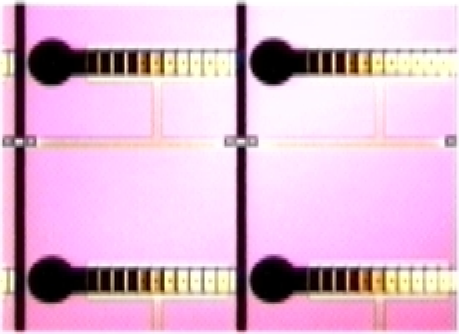
small cheap modules for tile-able displays

MEMS Mirror Array (binary)
(6x6 array for prototype)

- Initial OOP force from residual stress
- State memory from actuation hysteresis
- XY addressing
- ~200 Hz = no grayscale from pulse width modulation

Other possible MEMS devices for iMODS

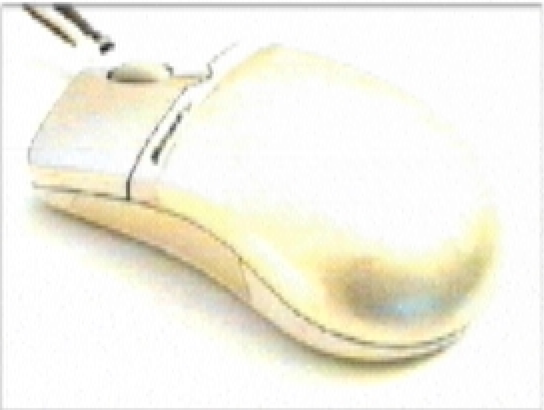
- Arrays of binary shutters
- Single 2D scanning mirror for raster generation



Somewhat less exotic

Sensors for UI

- Touch mouse/Touch PDA (CHI 99)
- Video mouse (UIST 99)
- Wrist mouse
- String mouse
- Haptic lens
- Gyro wand
- Linear camera



Physical UI

Sensor-based interaction ...

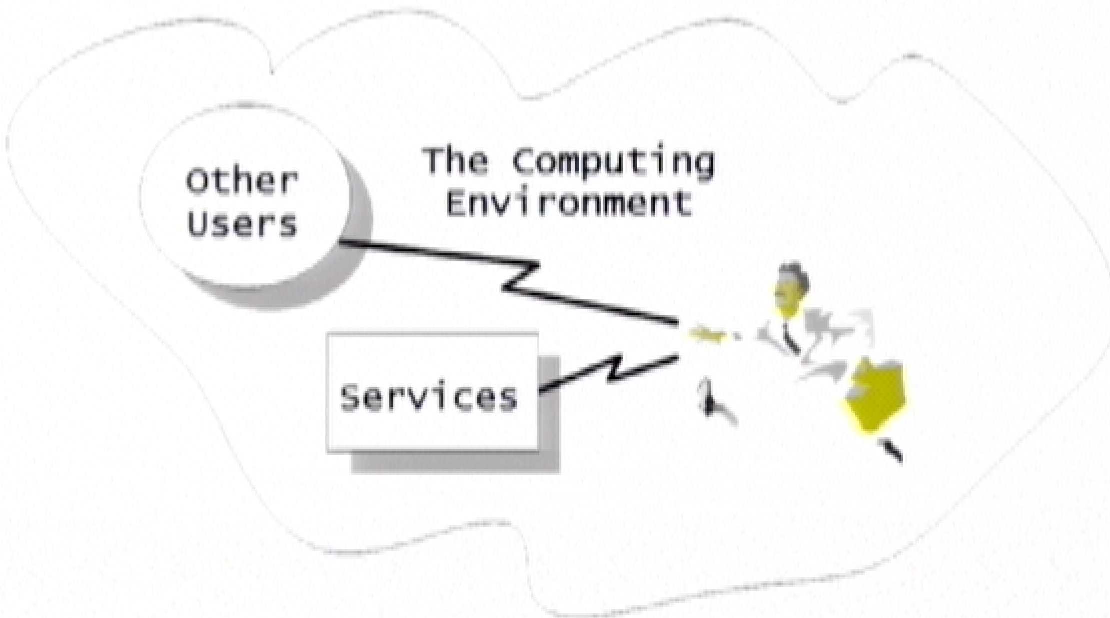
Capacitive touch slider, Mike Sinclair

IR range sensor, Mike Sinclair

Multi-sensor iPaq – Ken Hinckley, Jeff Pierce, Mike Sinclair, Eric Horvitz

iPAQ Minibrick – Victor Bahl, Eugene Shih

Invisible Computing: UI for the mobile user



Power supply for the New Century

- If each of us gains 10x the number of appliances, will we have the patience to change the batteries?

Power for computation

$$P = C_{eff} V^2 f$$

Grows 13% per year

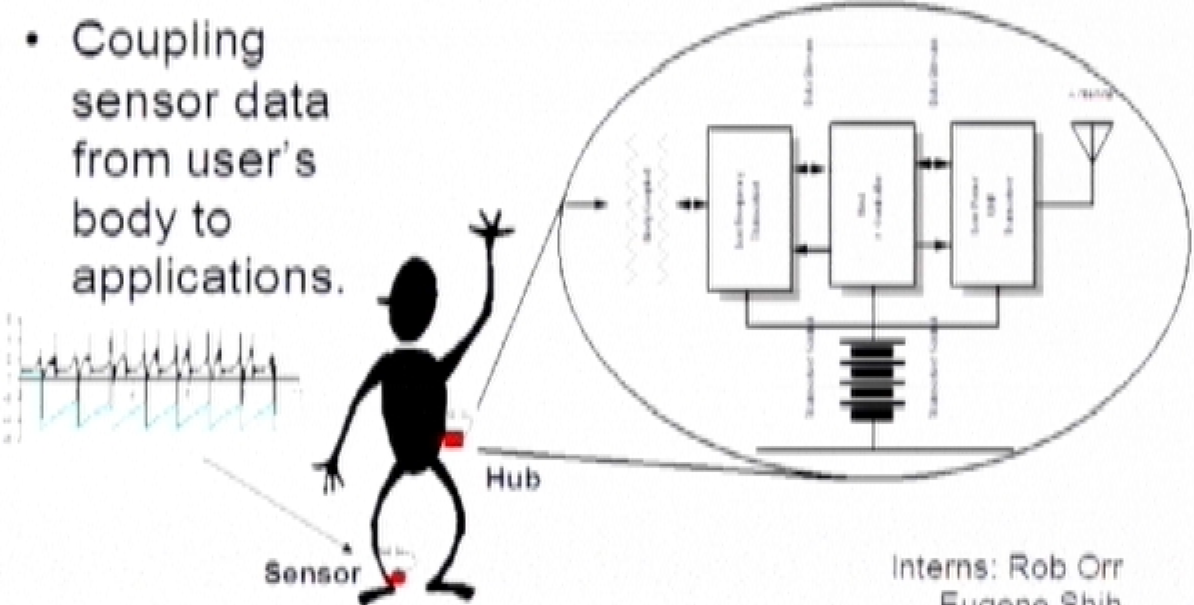
- Lower voltage
- Duty cycle management

Everyday form factors

- Non-intrusive
- Minimal

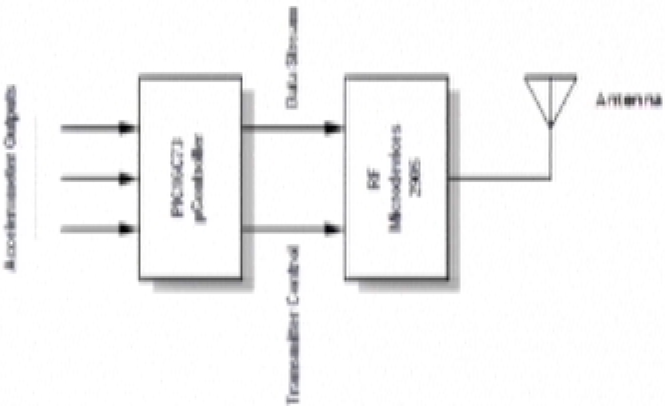
Mobile user

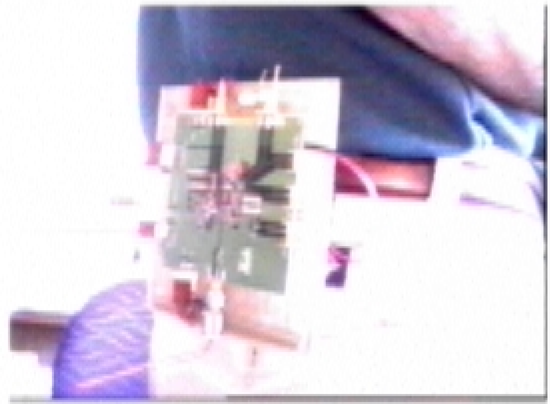
- Coupling sensor data from user's body to applications.



Interns: Rob Orr
Eugene Shih
Kurt Partridge

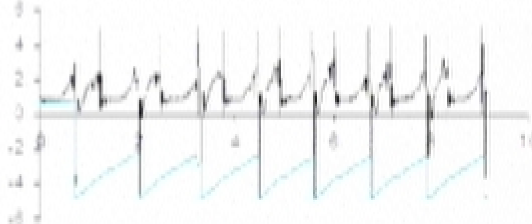
BodyLAN prototype



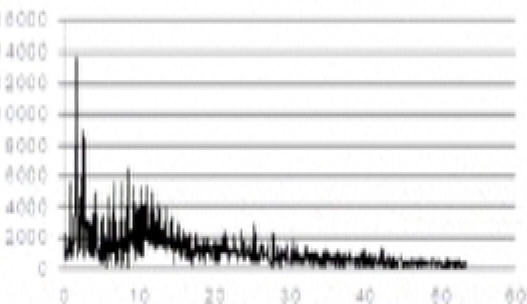


Sensor example (walking)

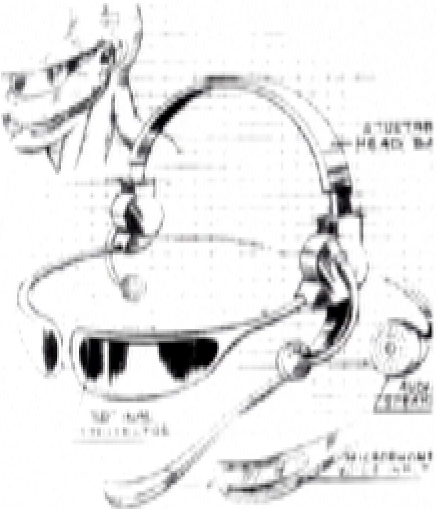
- Peak detector
  - Low duty cycle
  - Low bandwidth
- Raw signal
  - User identity



Heel-mounted accelerometer data (G force vs. time). Simple peak detector yields peak value and period.

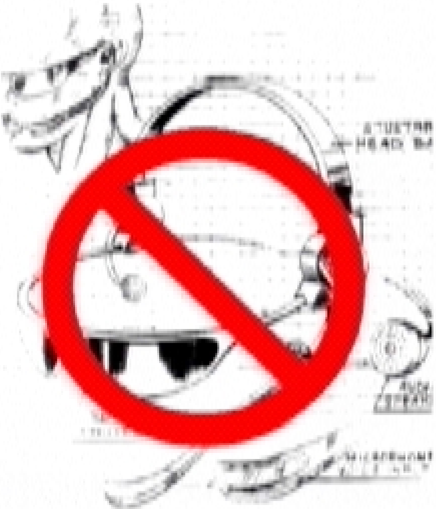


Grand-unified user experience



"Today, the most exciting development in interactive technology is the untethering of users from their desk-tops. We can imagine scientific, engineering, and business users with thoughtful looks on their faces, surrounded by their data as they wander through their offices and hallways, talking to their applications, listening to the results, and drawing on the walls. This represents a popular picture of smart environments and ubiquitous computing."

Grand-unified user experience



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Group direction

- Projects
  - Application/deployment
  - Not just fundamental technologies
- Personnel
  - Radio, communications, physical UI
- Products
  - Collaboration with HW group
  - Nudge UI towards more advanced features
- Partners
  - UI, LDUX, systems, vision, graphics, ...
  - UW, MIT, ...

The Lab

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